



Auditory, visual and auditory-visual memory and sequencing performance in typically developing children



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ABSTRACT

Objective: The study evaluated whether there exists a difference/relation in the way four different memory skills (memory score, sequencing score, memory span, & sequencing span) are processed through the auditory modality, visual modality and combined modalities.

Methods: Four memory skills were evaluated on 30 typically developing children aged 7 years and 8 years across three modality conditions (auditory, visual, & auditory-visual). Analogous auditory and visual stimuli were presented to evaluate the three modality conditions across the two age groups.

Results: The children obtained significantly higher memory scores through the auditory modality compared to the visual modality. Likewise, their memory scores were significantly higher through the auditory-visual modality condition than through the visual modality. However, no effect of modality was observed on the sequencing scores as well as for the memory and the sequencing span. A good agreement was seen between the different modality conditions that were studied (auditory, visual, & auditory-visual) for the different memory skills measures (memory scores, sequencing scores, memory span, & sequencing span). A relatively lower agreement was noted only between the auditory and visual modalities as well as between the visual and auditory-visual modality conditions for the memory scores, measured using Bland-Altman plots.

Conclusions: The study highlights the efficacy of using analogous stimuli to assess the auditory, visual as well as combined modalities. The study supports the view that the performance of children on different memory skills was better through the auditory modality compared to the visual modality.

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1. Introduction

Past researches regarding modality and memory have shown varying outcomes. There have been diverse ideas regarding whether memory is dependent or independent of modalities. The majority of the researchers favour the notion that memory varies depending on whether the stimuli are presented through the auditory modality or the visual modality, with the former being superior to the latter [1–4]. On the other hand, other researchers are of the view that memory is similar across the auditory and visual modalities [5–7]. Logie [2] noted that despite equivalent stimuli being used in evaluating memory through the auditory and visual modalities, there continued to be differences in the

performance of the two senses. To maintain stimuli constancy between the two modalities, for the visual task the participants recalled word sequences that they read and for the auditory task they recalled word sequences that they heard. It was noted in the study that word sequencing memory was superior through the auditory modality compared to the visual modality. The superior performance through the auditory modality was attributed to the ability of the participants to directly encode words heard phonologically, unlike visually presented words that required to be translated into a phonologically based code for temporary storage. Thus, it was construed that direct encoding occurred for verbal words but printed words required a two-step encoding.

Support that memory is processed through two channels in the visual modality is evident from the findings of Mayer [3]. Evaluating participants using verbal stimuli (spoken or printed words) or nonverbal stimuli (pictures, video, animation or environmental sounds), it was inferred that initially the visual text presented on a screen is processed through the visual channel and then it is

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processed through the auditory channel. The presence of such dual coding of printed words was earlier confirmed by Paivio, Philipchalk and Rowe [1], using a retrieval task. They reported that nonverbal items were remembered better in free recall whereas verbal items were remembered better in serial recall. They noted that auditory sounds were efficiently recalled in a serial/sequential manner, whereas visual words were not as efficiently recalled in the sequential manner. This was found to be true with verbal and nonverbal stimuli on a free as well as serial recall task. These distinctions in both symbolic and sensory modalities, as well as differences in the organization, enabled the researchers to confirm the presence of dual coding.

The findings of Goolkasian and Foos [4] also supports the notion that memory is processed differently in the auditory and visual modalities. Despite different presentation formats being used to evaluate the visual modality (picture and printed word formats) and spoken words to evaluate the auditory modality, it was reported that the auditory modality outperformed the visual modality in a recall task.

Unlike the above studies that suggest that memory processing/encoding is better through auditory modality compared to the visual modality, a few researchers have demonstrated that memory performance is similar in the auditory and visual modalities. Opposing the findings of studies that support difference in memory across the auditory and visual modalities, Avons [5] ascribed the difference noted in other studies to stimuli familiarity. The author remarked that auditory short term memory was most often studied using familiar verbal material such as words or digits that tapped serial order memory. On the other hand, visuospatial memory was measured in earlier studies using unfamiliar material such as patterns and matrices. These differences were considered to result in variation in performance across the modalities, rather than the modalities itself. Hence, Avons [5] conducted five different experiments to confirm the effect of stimuli in auditory and visual short term memory. From the experiments it was inferred that judgment of serial order affected memory performance. Thus, the study confirmed that difference in performance in modality resulted from the stimuli used instead of an actual difference in the modalities.

Further research was carried out by Ward, Avons and Melling [6] to demonstrate that differences in the method used in assessing modality performance could have resulted in differences in serial recall and not a modality-specific mechanism. This conclusion was drawn based on a series of 4 experiments using reconstructed unfamiliar facial parts from different faces (noses, mouths, eyes, ears, hair and chin/jaw) to evaluate the visual modality. The auditory modality was evaluated using nonwords. They concluded that visual and verbal short term memory tasks were independent of modality as well as type of material, but were dependent on the method of evaluation.

To infer whether the type of material and method used had an affect on memory performance across the auditory and visual modalities, Visscher et al. [7] studied participants using analogous visual and auditory stimuli. Gabor patch (static and moving Gaussian-windowed, sinusoidal gratings) were used as visual stimuli and moving ripples (broadband sounds with varying frequency of sinusoidal signal) were used as auditory stimuli. The researchers maintained the summed similarity and inter-item homogeneity of the stimuli. They reported that the auditory and the visual stimuli underwent very similar transformations while they were encoded and retrieved from memory. They concluded that by controlling the stimuli across modalities, the auditory and visual stimuli were encoded and retrieved in a similar manner.

Further, the effect of a combination of modalities on memory has also been researched. Frick [8] studied the effect of modality on digit span duration. It was observed that span duration was better

when both visual and auditory modalities were used together than when a single modality was used. In addition, it was noted by Moreno and Mayer [9] that the performance of students improved when verbal stimuli (narration) were presented also through the auditory modality rather than only with visual stimuli (texts or animation). They observed that mixed modality presentation was superior to the independent presentation through the auditory and visual modalities. Further, it was noted that in the mixed modality presentation, information was processed through auditory and visual working memory, facilitating better attention. This was considered to result in a connection between the two modalities.

Similarly, studies using different procedures [10,11] have also supported the notion of enhancement in performance with the use of simultaneous presentation of auditory and visual stimuli, instead of independent modality presentations. Hocking and Price [11], demonstrated this bimodal enhancement in performance in an imaging study. By simultaneously presenting auditory (verbal) and visual (print) stimuli, they showed that these stimuli activated left superior temporal sulcus, an area in the brain responsible for audiovisual integration. The study showed that verbal content of the stimuli facilitates audiovisual integration. Similarly, the findings on dual task retention [10] of items through two modalities were found to be better when compared with single modalities. These studies confirm enhanced performance through combined modalities over a single modality.

From the review of literature, it is evident that there exists considerable controversy regarding whether the auditory and the visual memory are similar or different. The studies that do support the existence of a superior performance of the auditory memory over visual memory, have generally not utilized analogous stimuli. Additionally, while studies have been carried out to evaluate each modality independently, studies evaluating bimodal memory performance [10,11] are limited. Thus, using analogous auditory and visual stimuli that are commonly used, the present study was undertaken to evaluate whether there exists a difference in the way the four different memory skills (memory score, sequencing score, memory span, & sequencing span) are processed through the auditory modality, visual modality and the combined modality condition.

2. Methods

The current research is a part of a larger study where children were evaluated on four processes/higher order cognition skills (separation/closure, integration, duration pattern perception, & memory & sequencing). The four processes/higher order cognitive skills were evaluated separately through the auditory and visual modalities as well as in the combined modality condition (auditory-visual). In the current article, information is provided regarding the memory and sequencing abilities of typically developing children in three modality conditions (auditory, visual, & auditory-visual).

2.1. Participants

Thirty typically developing children, categorized into two age groups having equal number of children, were studied. The children included in the study were aged 7 years (≥ 7 to < 7 years) and 8 years (≥ 8 to < 8 years) and had a minimum of two years of formal training in schools where English, a non-native language to them, was taught. Further, the participants were required to have normal air-conduction and bone-conduction thresholds in the octave frequencies 250 Hz to 8 kHz and 250 Hz to 4 kHz, respectively. To confirm that they had normal middle ear functioning, they were required to A-type tympanograms with acoustic reflexes present.

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